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ORIGINAL ARTICLE

Is there any association between age at menarche and anthropometric indices? A 15-year follow-up population-based cohort study

Maryam Farahmand[1] · Fahimeh Ramezani Tehrani[1] · Davood Khalili[2,3] · Leila Cheraghi[3] · Fereidoun Azizi[4]

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Abstract

Anthropometric indices (AI) have been known to be associated with age at menarche (AAM). The aim of this longitudinal study was to evaluate the changes in AI and its association with AAM in a community-based population in Iran. From among 10,192 women, we included 6818, aged ≥ 10 years, who were post-menarche at the time of entering the study and their AAM ranged between 8 and 18 years. Study subjects were divided into groups by tertiles birth cohort (BC) (born ≤ 1939, 1940–1969, and ≥ 1970) and AAM (≤ 11, 12–15, and ≥ 16 years). Generalized estimating equation analysis was performed to evaluate the association between changes of AI in different BCs with AAM groups. Overall mean of AAM was 13.5 ± 1.4 years. Mean body mass index (BMI) was significantly increased over time more in those with early AAM (≤ 11 years) compared to those with AAM ≥ 16 years; changes in mean BMI of 1.24 kg/m^2 (95% CI 0.32, 2.15), 2.61 kg/m^2 (95% CI 1.90, 3.33), and 3.99 kg/m^2 (95% CI 2.46, 5.51) in BC ≥ 1970, BC (1940–1969), and, BC ≤ 1939, respectively.

Conclusion: Our findings showed an inverse association of AAM with mean BMI, waist to height ratio, and waist circumference, an association weaker in younger women compared to other age groups.

What is Known:
- *Limited data are available on the association of menarcheal age with anthropometric indices.*
- *Previous studies reported conflicting and inclusive results of this association.*

What is New:
- *Our results can provide beneficial information on the association of menarcheal age with anthropometric indices based on different age groups.*
- *This long follow-up study shows an association of menarcheal age with anthropometric indices which are stronger in older women except for height.*

Keywords Menarcheal age · Body mass index · Birth cohort · Generalized estimating equations · Obesity · Waist to height ratio

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✉ Fahimeh Ramezani Tehrani
ramezani@endocrine.ac.ir; framezan@post.harvard.edu

Maryam Farahmand
mfarahmand14@yahoo.com; Farahmand@endocrine.ac.ir

Davood Khalili
dkhalili@endocrine.ac.ir

Leila Cheraghi
Leila_cheraghi63@yahoo.com

Fereidoun Azizi
azizi@endocrine.ac.ir

[1] Reproductive Endocrinology Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran

[2] Prevention of Metabolic Disorders Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran

[3] Department of Epidemiology and Biostatistics, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran

[4] Endocrine Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Abbreviations

AAM	Age at menarche
AI	Anthropometric indices
ANOVA	Analysis of variance
BC	Birth cohort
BMI	Body mass index
CI	Confidence interval
GEE	Generalized estimating equation
IQRs	Interquartile ranges
WC	Waist circumference
WHtR	Waist to height ratio
SD	Standard deviation
TLGS	Tehran Lipid and glucose study

Introduction

Increased attention is being focused on puberty timing, especially in recent years, because of higher rates of psychopathological disorders/events occurring in girls due to early puberty [1]. Age at menarche (AAM), mostly dependent on genetic factors, is influenced by lifestyle, socio-economic, and environmental factors [2]. Findings of studies show that early menarche is a risk factor for cardiovascular morbidity and mortality [3], type 2 diabetes [4], eating disorders [5], and depression [6].

Body composition changes significantly during the puberty period, although it is not clear yet whether puberty comes first or increased adiposity or vice versa [7]. Furthermore, central obesity, measured by waist circumference (WC) and the waist-height ratio (WHtR), increases the risk for metabolic and cardiovascular disorders among adolescents [8].

Considering the escalating prevalence of cardiovascular risk factors, e.g., obesity and diabetes over the last three decades and their association with anthropometric indices (AI), e.g., body mass index (BMI), waist to height ratio (WHtR), and waist circumference (WC), identifying changes in AI is vital [9]. An association between early puberty among girls and increased body mass index (BMI) in adulthood has been reported [10]. Additionally, results of studies show positive association with height and negative ones with WC and AAM, with decrease in adult BMI consequently delaying pubertal timing [11–14]. However, Kim et al. (2010) reported early menarche to be directly associated with height and BMI in adolescence [15]. Sperrin et al. (2016) reported that BMI changes are dependent on height, with taller persons gaining less weight during their lifetime, viz. women, a hypothesis they suggest must be verified in other cohorts, preferably at different stages of birth cohort (BC) during their lifetime [16].

It is still unclear whether AAM actually has a causal effect on adulthood obesity, or changes in anthropometric indices, and whether this association remains after adjustment for confounding factors which affect the AAM, as in physical activity, pubertal adiposity, or individual socio-economic factors [13, 17].

We aimed to investigate whether AAM affects AI changes during a women's life span, and if so, does this effect vary in different BCs using data of groups of participants of the Tehran Lipid and Glucose Study (TLGS), a 15-year follow-up with 3-year intervals.

Method

Subjects

The present study was approved by the ethical review board of the Research Institute for Endocrine Sciences, approval number: IR.SBMU.ENDOCRINE.REC.1396.564. Written informed consent was obtained from all subjects. For the purpose of the present study, participants were selected from the Tehran Lipid and Glucose Study (TLGS) [18], which is an ongoing prospective study, initiated in 1998, with the aim of determining the prevalence of non-communicable disease risk factors. For this study, 15,005 individuals, aged ≥ 3 years, were selected from a geographically defined population. The TLGS has two major components: a cross-sectional study of non-communicable diseases and associated risk factors, and a prospective 20-year follow-up at 3-year intervals. Information on various risk factors for non-communicable diseases, demographic variables, and reproductive histories was collected during face-to-face interviews, conducted every 3 years by trained interviewers, using a comprehensive questionnaire, general physical examination, height and weight measurements, and blood sample collection. Details on measurement methods have been published elsewhere [19].

At initiation of the study, 10,192 post-menarcheal women, aged ≥ 10 years in the TLGS, whose AAM ranged 8 to 18 years, were subdivided into three groups according to their birth date using BC tertiles of BC ≤ 1939, 1940–1969, and ≥ 1970 and were then subdivided into three groups based on AAM (≤ 11, 12–15, and ≥ 16).

Measurements

The occurrence of the first menstrual period (AAM) was documented by asking the question "how old were you when your first menstruation occurred." A probe question such as "At which grade did you have first menstruation" was used to improve the reliability of the main question. Birth date was identified by checking their birth certificates. In this study, AI included height, WC, BMI, and WHtR. Subjects' weight was measured when they were minimally clothed using a digital scale (Seca 707, Hanover, MD, USA), and rounded to the nearest 100 g. Similarly, height was measured with a tape measure without shoes in a standing position and normal posture of

shoulders. WC was measured using a scratched tape meter, at the level of the umbilicus, without any pressure to body surface and recorded to the nearest 0.1 cm. BMI was calculated as weight in kilograms (kg) divided by height squared (m^2).

Statistical analyses

Continuous variables were assessed for normality using the Kolmogorov–Smirnoff test. Continuous variables were reported as mean standard deviation (SD) or by medians with interquartile ranges (IQRs) (the range between the 25th and 75th percentiles) due to non-normal distribution, and categorical variables were expressed by numbers and percentages (*n* [%]). Analysis of variance (ANOVA), Kruskal-Wallis (whichever was appropriate), and chi-square test (for categorical variables) were used for comparing characteristics of subjects at the time of recruitment.

Comparison of average changes in AI (outcome) from baseline to the fourth follow-up between AAM groups and BCs was done using the generalized estimating equations (GEE) analysis. Interaction terms between AAM groups and BC were included in models to explore the possibility of BC specific associations; to do this, BC was included in all the models as an ordinal variable. Model 1 was adjusted for age at each follow-up, and model 2 in addition to age was adjusted for smoking status, education level, parity, and physical activity. Subjects with AAM ≤ 11 years and BC ≥ 1970 were considered as the reference group.

Model 1

$$\begin{aligned}\text{Anthropometric indices} = {} & \beta_0 + \beta_1 \text{age} + \beta_2 \text{follow-up} \\ & + \beta_3 \text{BC} + \beta_4 \text{AAMgroup 1} \\ & + \beta_5 \text{AAMgroup 2} \\ & + \beta_6 \text{AAMgroup 1} \times \text{BC} \\ & + \beta_7 \text{AAMgroup 2} \times \text{BC}\end{aligned}$$

Model 2

$$\text{Anthropometric indices} = \beta_0 + \beta_1 \text{age} + \beta_2 \text{follow} - \text{up} + \beta_3\ \text{BC} + \beta_4 \text{AAMgroup 1} + \beta_5 \text{AAMgroup 2} + \beta_7 \text{smoking} + \beta_8 \text{parity} + \beta_9 \text{physical activity} + \beta_{10} \text{education level 1} + \beta_{11} \text{education level 2} + \beta_{12} \text{AAM group 1} \times \text{BC} + \beta_{13} \text{AAM group 2} \times \text{BC}.$$

where anthropometric indices include BMI, WC, WHtR, and height; age was considered at each follow-up; BC was birth cohort; AAM group 1 and AAM group 2 were age at menarche 12–15 years and ≥ 16 years, respectively (AAM ≤ 11 was considered as reference group); and education level 1 was high school and lower and education level 2 was diploma (reference group: university degree).

The coefficients were estimated for each BC using the lincom STATA command and were run two sets of models.

Statistical analysis was done using STATA software version 13.0 (Statacorp, College Station, TX) and SPSS software, version 22 (SPSS Inc., Chicago, IL, USA), considering significance level at $P < 0.05$ and confidence interval (CI) as 95%.

Results

Characteristics of study subjects according to their birth cohort and age at menarche are presented in Table 1. The means of age, BMI, and height were 65.4 ± 4.5, 43.3 ± 8.5, and 21.5 ± 5.4 years; 28.8 ± 4.4, 28.6 ± 4.7, and 23.5 ± 4.6 kg/m^2; and 152.3 ± 5.4, 156.3 ± 5.7, and 159.2 ± 5.8 cm in BC 1 (≤ 1939), 2 (1940–1969), and 3 (≥ 1970), respectively. The means of WC and WHtR were 95.4 ± 10.8, 90.2 ± 11.9, 76.3 ± 10.7 cm and 0.63 ± 0.07, 0.58 ± 0.08, and 0.48 ± 0.07 in BCs 1, 2, and 3, respectively.

According to our findings, there was a positive association between AAM and height, and a negative association between AAM and BMI, WHtR, and WC, associations that were stronger among older women (Fig. 1).

The GEE analysis of anthropometric data except for height indicated that at different levels of BC, the association of AAM with mean BMI, WC, and WHtR differed (model 1 and model 2).

Findings of Table 2 showed that in both models ($P_{int} < 0.05$) after adjustment for all variables (model 2), women with AAM ≥ 16 years compared to those with AAM ≤ 11 years were associated with a change in BMI of − 1.24 kg/m^2 (95% CI − 2.15, − 0.32) in the BC ≥ 1970. This value for the BC (1940–1969) was − 2.61 kg/m^2 (95% CI − 3.33, − 1.90) and − 3.99 kg/m^2 (95% CI − 5.51, − 2.46) for the BC ≤ 1939. Moreover, women with AAM between 12 and 15 years, compared to those with AAM ≤ 11 years, were associated with a change in BMI of − 0.66 kg/m^2 (95% CI − 1.38, 0.58) in BC ≥ 1970. This value in the BC (1940–1969) was − 1.79 kg/m^2 (95% CI − 2.41, − 1.18) and in the BC ≤ 1939 was − 2.93 kg/m^2 (95% CI − 4.26, − 1.60).

Furthermore, in both models ($P_{int} < 0.05$), after adjustment for all variables, women with AAM ≥ 16 years compared to those with AAM ≤ 11 years were associated with a change in WC by − 4.26 cm (95% CI −5.82, −2.71) in BC ≥ 1940–1969. This value for BC ≤ 1939 was − 6.99 cm (95% CI − 10.31, − 3.66). As well, participants with AAM of 12–15 years were associated with a change in WC of − 3.00 cm (95% CI − 4.34, − 1.66) in BC (1940–1969) and − 5.55 cm (95% CI − 8.45, − 2.65) in BC ≤ 1939 compared to other women with AAM ≤ 11 (Table 2, model 2).

Table 1 Characteristics of subjects according to the tertiles of birth cohorts and age at menarche

Variables	Born in ≤ 1939 N = 595			*P* value	Born in 1940–1969 N = 3481			*P* value	Born in ≥ 1970 N = 2742			*P* value
	AAM (years)				AAM (years)				AAM (years)			
	≤ 11	12–15	≥ 16		≤ 11	12–15	≥ 16		≤ 11	12–15	≥ 16	
BMI** (kg/m^2)	30.1 ± 4.2	28.8 ± 4.4	28.1 ± 4.2	0.16	30.0 ± 4.7	28.7 ± 4.6	27.8 ± 4.9	< 0.001	24.7 ± 4.7	23.7 ± 4.6	23.6 ± 4.0	0.21
WHtR**	0.66 ± 0.07	0.63 ± 0.07	0.61 ± 0.07	0.05	0.59 ± 0.07	0.58 ± 0.08	0.57 ± 0.08	0.01	0.49 ± 0.07	0.48 ± 0.07	0.47 ± 0.06	0.8
WC** (cm)	99.0 ± 9.1	95.5 ± 10.9	94.3 ± 10.4	0.26	91.8 ± 11.2	90.2 ± 11.9	89.3 ± 12.0	0.09	78.4 ± 11.3	76.8 ± 10.8	77.2 ± 10.0	0.73
Height (cm)	149.8 ± 6.2	152.2 ± 5.3	153.9 ± 5.5	0.02	155.4 ± 6.0	156.3 ± 5.7	157.0 ± 5.9	0.009	157.7 ± 6.4	159.1 ± 5.7	160.6 ± 6.1	< 0.001
SBP** (mm Hg)	145.9 ± 21.5	139.4 ± 22.6	138.5 ± 21.5	0.25	118.6 ± 19.1	118.6 ± 18.0	117.8 ± 16.8	0.70	104.9 ± 10.6	105.7 ± 10.7	106.9 ± 10.8	0.19
DBP** (mm Hg)	84.7 ± 9.0	81.7 ± 11.9	83.8 ± 12.2	0.15	78.5 ± 11.4	78.5 ± 10.4	78.2 ± 10.2	0.87	71.2 ± 9.5	71.3 ± 8.7	71.4 ± 8.7	0.98
TC** (mg/dl)	236.9 ± 48.4	247.6 ± 48.4	236.4 ± 48.2	0.57	216.2 ± 38.4	215.4 ± 45.9	218.1 ± 47.5	0.57	166.6 ± 30.7	172.7 ± 35.2	175.5 ± 35.7	0.46
HDL** (mg/dl)	44.5 ± 10.3	46.3 ± 11.4	47.4 ± 10.9	0.79	43.5 ± 11.3	44.2 ± 11.1	44.9 ± 11.1	0.37	44.1 ± 9.9	44.4 ± 10.9	46.0 ± 11.5	0.13
TG*** (mg/dl)	176 (121, 229)	179 (130.8, 258.3)	152 (120.5, 199.5)	0.6	145 (98.5, 207.5)	149 (102, 211)	148 (100, 215.5)	1.0	94 (73, 127)	93 (68, 128)	92 (66.3, 121.5)	0.6
FBS** (mg/dl)	108.3 ± 28.8	116.1 ± 49.4	115.5 ± 47.5	0.9	98.9 ± 35.0	99.8 ± 36.2	98.7 ± 35.8	0.84	85.7 ± 7.6	85.6 ± 8.5	86.4 ± 13.2	0.49
BS*** (mg/dl)	130 (108, 147)	130 (110, 158)	128.5 (103.8, 165.5)	0.8	109 (92, 132)	111 (94, 136)	110 (92.5, 131)	0.7	95 (86, 112)	94 (82, 109)	96 (83, 110.8)	0.4
Parity**	6.2 ± 2.5	5.9 ± 2.4	5.8 ± 2.1	0.85	3.0 ± 1.6	3.3 ± 1.8	3.4 ± 1.7	0.11	0.3 ± 0.6	0.5 ± 0.8	0.7 ± 0.9	0.09
Physical activity***	13.9 (0.6, 28.6)	13.9 (2.8, 27.8)	13.3 (4.0, 31.0)	0.87	19.8 (9.8, 37.6)	17.9 (7.4, 33.7)	17.0 (7.9, 32.8)	0.57	13.9 (4.0, 25.1)	13.9 (4.0, 27.8)	13.9 (5.6, 27.8)	0.66
Ever smoker* (yes)	3 (15.8)	59 (11.6)	2 (3.0)	0.08	16 (9.5)	244 (8.3)	40 (11.0)	0.20	10 (6.0)	151 (6.4)	20 (10.1)	0.12
Educational level*												
High school and lower	18 (94.7)	493 (96.9)	65 (97.0)	0.21	86 (50.9)	1671 (56.7)	216 (59.5)	0.46	11 (6.6)	247 (10.4)	26 (13.1)	0.31
Diploma	0 (0.0)	13 (2.6)	1 (1.5)		63 (37.3)	975 (33.1)	114 (31.4)		85 (51.2)	1096 (46.1)	91 (45.7)	
University degree	1 (5.3)	3 (0.6)	1 (1.5)		20 (11.8)	303 (10.3)	33 (9.1)		70 (42.2)	1032 (43.5)	82 (41.2)	

ANOVA, Kruskal-Wallis, and chi-square test were used as appropriate

AAM age at menarche, *BMI* body mass index, *WHtR* waist to height ratio, *WC* waist circumference, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *TC* total cholesterol, *HDL* high-density lipoprotein, *FBS* fasting blood sugar, *TG* triglyceride

*Number and percentage

**Mean ± SD

***Median (Q1, Q3)

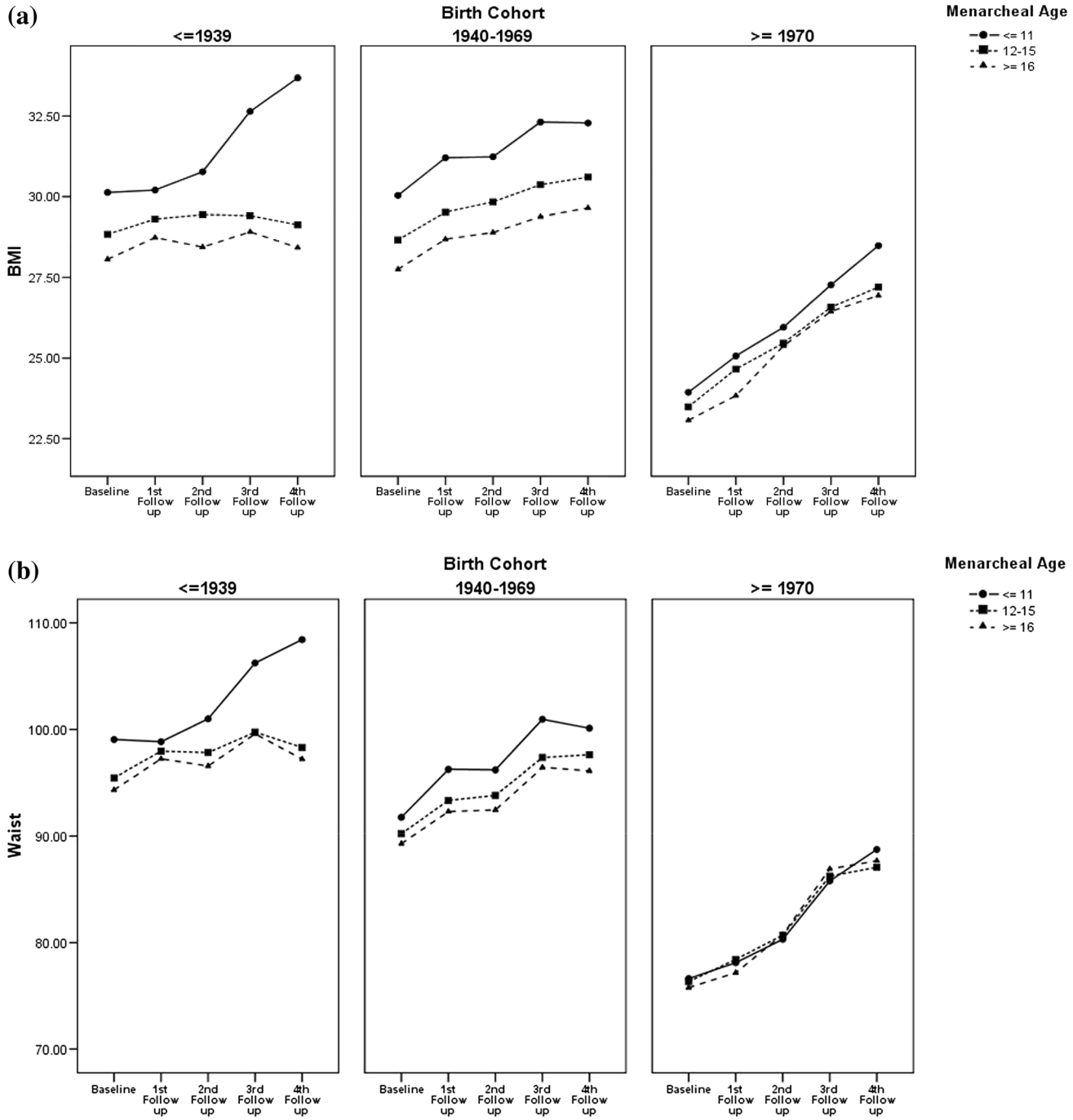

Fig. 1 Trend of anthropometric indices from 1998 to 2015 by age at menarche group in different birth cohorts. **a** Trend of BMI, **b** trend of waist, **c** trend of WHtR, **d** trend of height. Abbreviations: BMI, body mass index; WHtR, waist to height ratio

Results of Table 3 showed that overall in both models ($P_{int} < 0.05$) after adjustment for all variables, women with AAM ≥ 16 years compared to those with AAM ≤ 11 years were associated with a change in WHtR of − 0.02 (95% CI − 0.03, − 0.01) in BC ≥ 1970. This value in BC ≥ 1940–1969 was − 0.04 (95% CI − 0.05, − 0.03) and in BC ≤ 1939 was − 0.06 (95% CI − 0.08, − 0.04). In addition, participants with AAM 12–15 years were associated with a change in WHtR compared to those with AAM ≤ 11 years of − 0.02 (95% CI − 0.03, − 0.01) in BC (1940–1969) and − 0.04 (95% CI − 0.06, − 0.02) in BC ≤ 1939 (Table 3, model 2).

Results of GEE analysis for height changes indicate that there was no interaction between the AAM group and BC in both models ($P_{int} > 0.05$). In other words, the positive associations between AAM and changes of mean height in the different BCs were similar. Results of the multivariate adjusted model showed that women with AAM ≥ 16 years and AAM 12–15 years were 2.14 cm

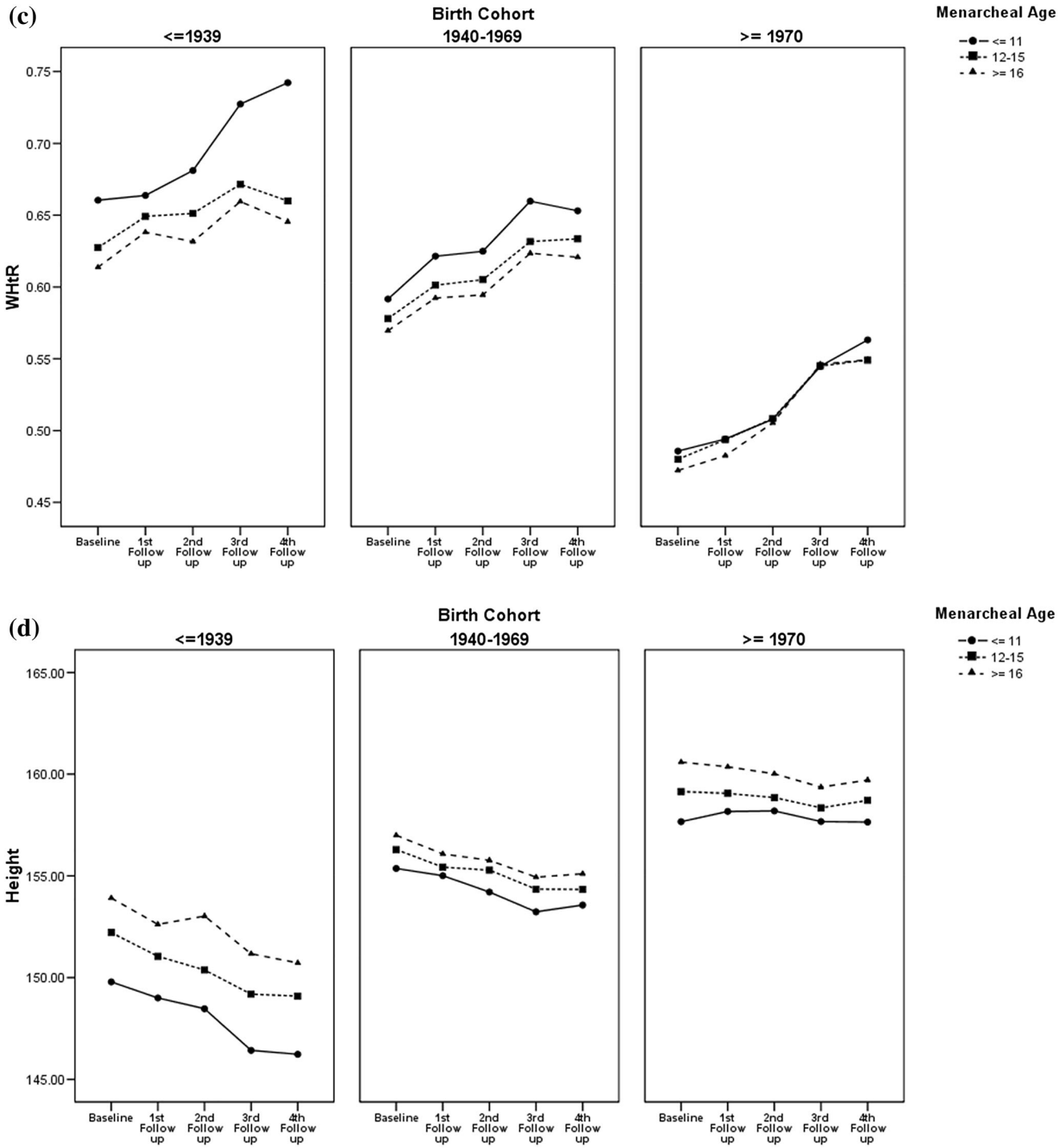

Fig. 1 (continued)

(95% CI 1.40, 2.89) and 0.94 cm (95% CI 0.33, 1.55) taller than those with AAM ≤ 11 years.

Discussion

In this population-based cohort study with a 15-year follow-up, we found a negative association between AAM and BMI, WC, and WHtR that was intensified among those born earlier, suggesting a fading effect of menarcheal age on adulthood obesity among younger generations.

Results of studies have shown positive and negative associations between adulthood height and WC with AAM, respectively; those with delayed puberty experienced less BMI increase during adulthood [11–14]. However, Kim et al. reported that early menarche positively associated with height

Table 2 Estimated effect of age at menarche group on body mass index and waist circumference using the generalized estimating equations model

Dependent variable		BMI				WC			
		Model 1		Model 2		Model 1		Model 2	
Covariate	AAM (years)	β (95% CI)	*P* value	β (95% CI)	*P* value	β (95% CI)	*P* value	β (95% CI)	*P* value
BC ≥ 1970	≥ 16	− 1.47 (− 2.36, − 0.58)	0.001	− 1.24 (− 2.15, − 0.32)	0.008	− 2.13 (− 4.08, − 0.17)	0.033	− 1.54 (− 3.55, 0.48)	0.135
	12–15	− 0.88 (− 1.57, − 0.19)	0.013	− 0.66 (− 1.38, 0.58)	0.072	− 1.00 (− 2.51, 0.53)	0.201	− 0.45 (− 2.03, 1.13)	0.578
	≤ 11	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
BC 1940–1969*	≥ 16	− 2.57 (− 3.26, − 1.87)	< 0.001	− 2.61 (− 3.33, − 1.90)	< 0.001	− 4.26 (− 5.78, − 2.74)	< 0.001	− 4.26 (− 5.82, − 2.71)	< 0.001
	12–15	− 1.61 (− 2.20, − 1.01)	< 0.001	− 1.79 (− 2.41, − 1.18)	< 0.001	− 2.66 (− 4.00, − 1.35)	< 0.001	− 3.00 (− 4.34, − 1.66)	< 0.001
	≤ 11	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
BC ≤ 1939*	≥ 16	− 3.67 (− 5.13, − 2.20)	< 0.001	− 3.99 (− 5.51, − 2.46)	< 0.001	− 6.39 (− 9.61, − 3.17)	< 0.001	− 6.99 (− 10.31, − 3.66)	< 0.001
	12–15	− 2.33 (− 3.60, − 1.07)	< 0.001	− 2.93 (− 4.26, − 1.60)	< 0.001	− 4.32 (− 7.10, − 1.54)	0.002	− 5.55 (− 8.45, − 2.65)	< 0.001
	≤ 11	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref

P value < 0.05 was considered statistically significant. Model 1: adjusted for age at each follow-up and follow-up time, model 2: adjusted for variables in model 1 and smoking, education level, parity, and physical activity

CI confidence interval, *AAM* age at menarche, *BC* birth cohort, *BMI* body mass index, *WC* waist circumference

*The results were obtained using postestimation lincom Stata command

and BMI in adolescence [15]. Puberty is an especially important phase of life with significant physical, mental, and emotional variations; its timing indicates the overall health and nutrition status [20–22].

Menarche, a pivotal event of sexual maturation, is mostly dependent on genetic factors and influenced by lifestyles, socio-economic, and environmental factors [2]. Early menarche is a risk factor for cardiovascular morbidity and mortality [3], type 2 diabetes [4], eating disorders [5], and depression [6], whereas late menarche is associated with increased risk of CVD morbidity and mortality [23]. Menarche affects the health status of women via several biological and psychological pathways.

Early menarche accelerates exposure to gonadal steroids that could result in increases in abdominal fat and adiposity.

Remarkably, a quicker progression of pubertal stages was reported in girls with early menarche [24]; hyperandrogenemia may also have a role in increasing adult BMI [25]. In this regard, results of a study showed early adrenarche is associated with ovarian hyperandrogenism [26]. It seems the cause of hyperandrogenemia is the positive feedback regulation of gonadotropin release in the hypothalamus in response to elevated estrogen. In other words, ovarian response to elevated LH levels, which acts on the theca cells, can cause androgen excess. Although this issue is still unclear, the role of androgen has been known in insulin resistance and obesity [27–29].

Furthermore, increased susceptibility for weight gain in teenagers due to effects of an altered hormonal environment could affect their psychological development [30]. Accelerated physical changes of puberty in early adolescence compared to their peers could have adverse effects [24]. Therefore, elevated risk of obesity is associated with depression in early adolescents and can lead to a higher odds of depression, especially in late adolescence [31].The results of studies show an elevated risk of later obesity with depression especially among adolescent girls [32]; apparently, obesity may occur due to emotional eating behaviors, short time spent engaging in physical activity, and variations in adiposity due to antidepressant use. Obesity can also cause social isolation from others [33], leading to a defective cycle of depression and adult obesity. Furthermore, there is an association between early puberty in girls, who have lower academic and employment outcomes, compared to their peer groups [34].

There is another hypothesis that changing gonadal steroid exposure in early adolescence has psychological effects [35]. Actually, due to declining neural plasticity subsequent to the postnatal period, hormonal levels influence the brain chronologically. Therefore, early menarche can create an emotional response incompatible with the cognitive control system, whose effects appear in adolescence [36, 37]. Moreover, Iranian children and adolescents prefer Western dietary patterns, largely specified by the consumption of high-calorie

Table 3 Estimated effect of age at menarche group on waist to height ratio and height using the generalized estimating equations model

Dependent variable		WHtR				Height**			
		Model 1		Model 2		Model 1		Model 2	
Covariate	AAM (years)	β (95% CI)	*P* value	β (95% CI)	*P* value	β (95% CI)	*P* value	β (95% CI)	*P* value
BC ≥ 1970	≥ 16	− 0.021 (− 0.03, − 0.01)	0.001	− 0.02 (− 0.03, − 0.01)	0.015	2.24 (1.52, 3.00)	< 0.001	2.14 (1.40, 2.89)	< 0.001
	12–15	− 0.01 (− 0.02, 0.00)	0.059	− 0.01 (− 0.01, 0.00)	0.297	1.03 (0.43, 1.62)	0.001	0.94 (0.33, 1.55)	0.003
	≤ 11	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
BC (1940–1969)*	≥ 16	− 0.03 (− 0.05, − 0.03)	< 0.001	− 0.04 (− 0.05, − 0.03)	< 0.001	–	–	–	–
	12–15	− 0.02 (− 0.03, − 0.01)	< 0.001	− 0.02 (− 0.03, − 0.01)	< 0.001	–	–	–	–
	≤ 11	Ref	Ref	Ref	Ref	–	–	–	–
BC (≤ 1939)*	≥ 16	− 0.05 (− 0.07, − 0.03)	< 0.001	− 0.06 (− 0.08, − 0.04)	< 0.001	–	–	–	–
	12–15	− 0.03 (− 0.05, − 0.01)	< 0.001	− 0.04 (− 0.06, − 0.02)	< 0.001	–	–	–	–
	≤ 11	Ref	Ref	Ref	Ref	–	–	–	–

P value < 0.05 was considered statistically significant. Model 1: adjusted for age at each follow-up and follow-up time, model 2: adjusted for variables in model 1 and smoking, education level, parity, and physical activity

CI confidence interval, *AAM* age at menarche, *BC* birth cohort, *WHtR* waist to height ratio

*The results were obtained using postestimation lincom Stata command

**There is no interaction between MAG and BC levels in both models ($P_{int} > 0.05$)

snacks and fast foods [38]. In our study, the changes of the mean AI among AAM groups, compared to those of older women, are poorer, which may be due to this dietary pattern in younger women.

Research studies showed conflicting results regarding the association between menarche and body weight [39]. Findings of another cross-sectional study showed one year increase in age at menarche was associated with a decrease in mean BMI of almost 0.5 kg/m2 [40]. Additionally, studies reported a direct association with height and a negative one with WC and AAM, and reduction of adult BMI consequently delaying pubertal timing and a research also showed a negative association between menarche and BMI in adults [11–14, 41]. However, Kim et al. reported that early menarche directly associated with height and BMI in adolescence [15]. Sperrin et al. reported that BMI changes are dependent on height, as taller persons gain less weight during their lifetime, especially women [16]. In a cohort study, results showed a negative association between menarche and obesity, an association however that tends to differ among birth cohorts [42].

In addition, in recent decades, increasing globalization is strongly affecting particularly the younger generations [43, 44], which may partly be explained by the effects of AAM on AI during adulthood among those in the older BCs.

To the best of our knowledge, although the effects of AAM on adulthood obesity parameters have been reported, no other researchers have investigated intergenerational effects on this association.

We have a relatively large number of participants with a long-enough follow-up, whose anthropometric parameters were measured 5 times at 3-year interval on an average. Using robust statistical methods for analyzing the data and adjusting for the most important potential confounders is another strength of the present study.

Our study, however, has some limitations as well; age at menarche was self-reported and therefore susceptible to recall bias; however, since age at menarche was documented in each follow-up, the effect of recall error may be minimal. Moreover, our results might be confounded by not having considered other lifestyle factors, such as diet.

In conclusion, nowadays, due to globalization and great changes in lifestyles, the strong impact of age at menarche on adulthood obesity can be controlled, by focusing attention on lifestyle modification, the main prerequisite of all communities. It is highly recommended that clinicians be made aware about the reduction of the effect of AAM as an influential factor negatively affecting adulthood obesity, and the need to pay more attention to the lifestyles mediators especially in younger women. We recommend further studies among other populations to explore the association between AI with AAM with adjusted other lifestyle factors, such as diet and physical activity.

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Authors' contributions MF contributed to the study design, data analysis, manuscript drafting, and critical discussion. FRT contributed to the study design and execution, data analysis, manuscript drafting, and critical discussion. DK contributed to the study design and execution, and data analysis. LC contributed to data analysis and manuscript drafting. FA contributed to the study design and execution and manuscript drafting.

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